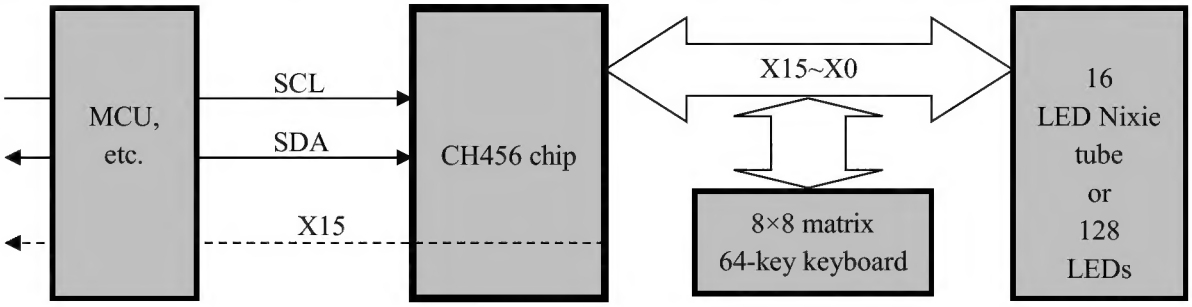
16-Bit LED Nixie Tube Driver and Keyboard Control Chip CH456

Datasheet
Version: 1A
http://wch.cn

1. Overview

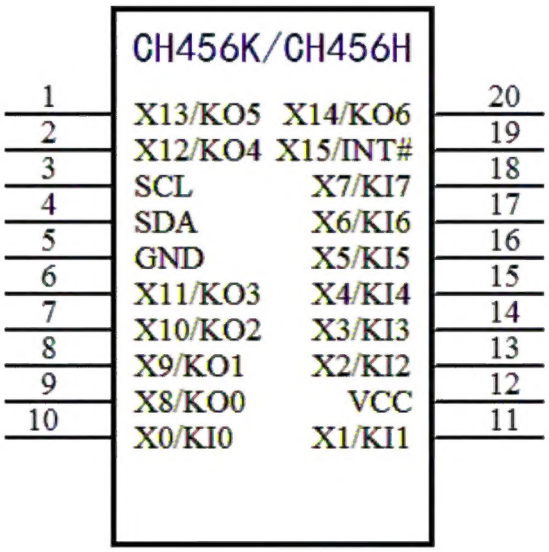
CH456 is a 16-bit LED Nixie tube display driver and keyboard scan control chip. CH456 has a built-in clock oscillation circuit, which can dynamically drive up to 16 LED Nixie tubes or 128 LEDs and can also scan the keyboard with 64 keys. CH456 exchanges data with a MCU through a 2-wire serial interface.

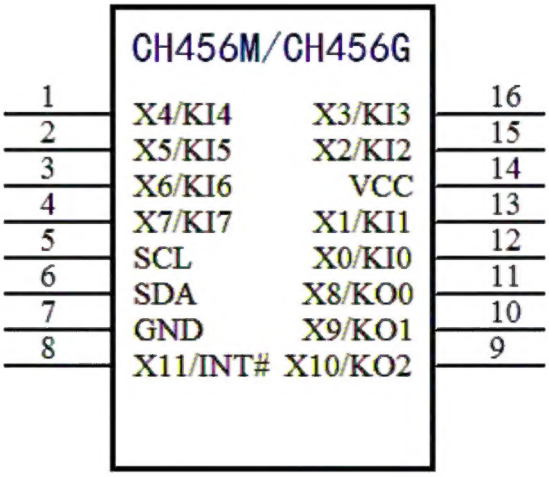


2. Features

- Built-in display current driving stage, segment current 25mA, word current 150mA.
- Dynamic display scanning control, direct drive of 16 LED Nixie tubes or 128 LEDs.
- Internal current limiting, provide multi-stage brightness control through duty ratio setting.
- Built-in 64-key keyboard controller, based on 8×8 matrix keyboard scan.
- Dual-purpose keyboard interrupt active at low level, key release flag bit for query key to be pressed down and released.
- Some unused display drive pins X12 ~ X15 can be used as the GPO general-purpose output pin.
- High speed two-wire serial interface, clock speed from 0 to 2MHz, compatible with 2-line I^2C bus, saving pins.
- Built-in clock oscillator circuit, no need to provide external clock or external oscillator components, more anti-interference.
- It supports the supply voltage of 3V, 3.3V and 5V.
- Support low-power sleep, save power, can be waked up by key or command operation.
- Provide DIP20, SOP20, DIP16 and SOP16 four lead-free packaging types, compatible with RoHS.

3. Package





Package	Width		Pitch of Pin		Instruction of Package	Ordering information
DIP20	7.62mm	300mil	2.54mm	100mil	Standard 20-pin dual in-line package	CH456K
SOP20	7.62mm	300mil	1.27mm	50mil	Standard 20-pin wide pin patch	CH456H
DIP16	7.62mm	300mil	2.54mm	100mil	Standard 16-pin dual in-line package	CH456M
SOP16	3.90mm	150mil	1.27mm	50mil	Standard 16-pin pin patch	CH456G

CH456K/H supports 16 LED Nixie tubes or 128 LEDs and 64 keys, CH456M/G supports 12 LED Nixie tubes or 96 LEDs and 32 keys

4. Pins

Pin No. for 20-pin package	Pin No. for 16-pin package	Pin Name	Type	Description
12	14	VCC	Power	Positive power supply, continuous current not less than 150mA
5	7	GND	Power	Common ground, continuous current not less than 150mA
10~11, 13~18	12~13, 15~16, 1~4	X0~X7 (KI0~KI7)	Three-status output and Keyboard scan input	Segment drive of LED Nixie tube, active at high level Word drive of LED Nixie tube, active at low level Keyboard scan input, active at high level, built-in pull-down resistor
9~7	11~9	X8~X10 (KO0~KO2)	Three-status output and Keyboard scan output	Segment drive of LED Nixie tube, active at high level Word drive of LED Nixie tube, active at low level Keyboard scan input, active at high level

6	8	X11 (KO3) (INT#)	Three-status output and Keyboard scan output	Segment drive of LED Nixie tube, active at high level Word drive of LED Nixie tube, active at low level Keyboard scan output, active at high level, It can be set as keyboard interrupt output, active at low level
2, 1, 20	None	X12~X14 (KO4~KO6)	Three-status output and Keyboard scan output	Word drive of LED Nixie tube, active at low level Keyboard scan output, active at high level, It can be set as GPO general-purpose output
19	None	X15 (KO7) (INT#)	Three-status output and Keyboard scan output	Word drive of LED Nixie tube, active at low level Keyboard scan output, active at high level, It can be set as keyboard interrupt output, active at low level
4	6	SDA	Open-drain output and input	Data input and output of 2-wire serial interface, Built-in pull-up resistor
3	5	SCL	Input	Clock input of two-wire serial interface

5. Functional Specification

5.1. General Specification

For data in this manual, those ending with B are binary numbers and those ending with H are hexadecimal numbers. Otherwise, they are decimal numbers. The bit marked as x indicates that the bit can be any value.

5.2. Display Driver

CH456 adopts dynamic scan drive for LED Nixie tubes and LEDs, and X0 to X15 are connected to the cathodes of 16 LED Nixie tubes respectively. When one pin absorbs current, the other pins do not. The segment G ~ segment A of the LED Nixie tube and the decimal point of the LED Nixie tube correspond to 8 dynamic converted segment drive pins of CH456 respectively. The CH456 has an internal current drive stage, which can directly drive 0.5 to 1 inch common cathode LED Nixie tube. The CH456 can also be connected to an 8×16 matrix LED array or 128 independent LEDs.

CH456 has 16 8-bit data registers, which are used to store 16-word data, corresponding to 16 LED Nixie tubes or 16 groups of LEDs driven by CH456, 8 LEDs in each group. The bits 7-0 of the word data in the data register correspond to the decimal points and segments G-A of 8 LED Nixie tubes respectively. For LED array, the data bit of each word data uniquely correspond to an LED. When the data bit is 1, the segment of the corresponding LED Nixie tube or LED will be on. When the data bit is 0, the segment of the corresponding LED Nixie tube or LED will be off. For example, the bit 0 of the third data register is 1, so the segment A of the corresponding third LED Nixie tube is on.

The following diagram shows the segment name of the LED Nixie tube.

The following table shows the dynamic correspondence between the current word-driven pin and the current segment-driven pin.

Current word pin	X0	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15
Segment pin S0/A	X4	X4	X4	X4	X0	X0	X0	X0	X0	X0	X0	X0	X0	X0	X0	X0
Segment pin S1/B	X5	X5	X5	X5	X1	X1	X1	X1	X1	X1	X1	X1	X1	X1	X1	X1
Segment pin S2/C	X6	X6	X6	X6	X2	X2	X2	X2	X2	X2	X2	X2	X2	X2	X2	X2
Segment pin S3/D	X7	X7	X7	X7	X3	X3	X3	X3	X3	X3	X3	X3	X3	X3	X3	X3
Segment pin S4/E	X8	X8	X8	X8	X8	X8	X8	X8	X4	X4	X4	X4	X4	X4	X4	X4
Segment pin S5/F	X9	X9	X9	X9	X9	X9	X9	X9	X5	X5	X5	X5	X5	X5	X5	X5
Segment pin S6/G	X10	X10	X10	X10	X10	X10	X10	X10	X6	X6	X6	X6	X6	X6	X6	X6
Segment pin S7/DP	X11	X11	X11	X11	X11	X11	X11	X11	X7	X7	X7	X7	X7	X7	X7	X7

5.3. Keyboard Scan

CH456 keyboard scan feature supports an 8×8 matrix 64-key keyboard. During keyboard scan, KO7~KO0 pins (i.e. X15~X8) are used for the column scan output, and KI7~KI0 pins (i.e. X7~X0) have internal pull-down resistors for the line scan input.

CH456 periodically inserts keyboard scan during the display driver scan. During keyboard scan, the pins KO7~KO0 output high voltage in sequence from KO0 to KO7, and the remaining pins output low voltage. The outputs of the pins KI7~KI0 are disabled. When no key is pressed, KI7~KI0 are pulled down to low voltage. When a key is pressed, for example, the key connecting KO3 and KI4 is pressed, KI4 detects high voltage when KO3 outputs high voltage. After anti-interference treatment, if CH456 is confirmed to detect a valid key, the key code will be recorded, and the keyboard interrupt active at low level will be generated through INT# pin (i.e. after enabling interrupt output of X15 or X11). At this time, the MCU can read the key code through the serial interface. CH456 does not generate any keyboard interrupt until a new valid key is detected. CH456 does not support combination key, and two or more keys cannot be pressed at the same time.

The key code provided by CH456 is 7-bit, bits 2-0 are column scan codes, bits 5-3 are line scan codes, and bit 6 is status code (1 when the key is pressed, 0 when the key is released). For example, when the key connecting KO3 and KI4 is pressed, the key code is 1100011B or 63H. After the key is released, the key code is usually 0100011B or 23H (or other values, but certainly less than 40H), where the column scan code corresponding to KO3 is 011B, and the line scan code corresponding to KI4 is 100B. The MCU can read the key code at any time, but it generally reads the key code when CH456 detects a valid key and produces keyboard interrupt. At this time, the bit 6 of the key code is always 1. In addition, if you need to know when the key is released, the MCU can read the key code regularly by inquiry until the bit 6 of the key code is 0.

The following table shows the key addressing for the 8×8 matrix between KI7 ~ KI0 and KO7 ~ KO0. As the key code is 7-bit, the bit 6 is always 1 when the key is pressed. When the key is pressed, the actual key code provided by CH456 is the key address in the table plus 40H, that is, the key code should be 40H-7FH.

Addressing	KO7/X15	KO6/X14	KO5/X13	KO4/X12	KO3/X11	KO2/X10	KO1/X9	KO0/X8
KI0/X0	07H	06H	05H	04H	03H	02H	01H	00H
KI1/X1	0FH	0EH	0DH	0CH	0BH	0AH	09H	08H
KI2/X2	17H	16H	15H	14H	13H	12H	11H	10H
KI3/X3	1FH	1EH	1DH	1CH	1BH	1AH	19H	18H
KI4/X4	27H	26H	25H	24H	23H	22H	21H	20H
KI5/X5	2FH	2EH	2DH	2CH	2BH	2AH	29H	28H
KI6/X6	37H	36H	35H	34H	33H	32H	31H	30H
KI7/X7	3FH	3EH	3DH	3CH	3BH	3AH	39H	38H

5.4. Serial Interface

CH456 has a two-wire serial interface realized by hardware, including two main signal lines: serial data clock input line SCL, serial data input and output line SDA. Among which SCL is an input signal line. SDA is a quasi-bidirectional signal line with pull-up resistors, and is at high level by default. In addition, X15 or X11 pins can be used as INT# pins after enabling interrupt output, outputs keyboard interrupt, and is at high level by default.

SDA is used for serial data input and output. The high level represents bit data 1, and the low level represents bit data 0. The sequence of serial data input is that the high bit is at the front and the low bit is at the back.

SCL is used to provide a serial clock, CH456 inputs data from SDA on its rising edge and outputs data from SDA on its falling edge.

SDA falling edge occurring during the SCL high level period is defined as the start signal of the serial interface, and SDA rising edge occurring during the SCL high level period is defined as the stop signal of the serial interface. CH456 receives and analyzes the command only after detecting the start signal. Therefore, when I/O pin resources of the MCU are short, SCL pin can be shared with other interface circuits while SDA pin state is unchanged. Both SCL and SDA pins can be shared with other interface circuits if it is possible to ensure that SDA pin changes only when SCL pin is at low level.

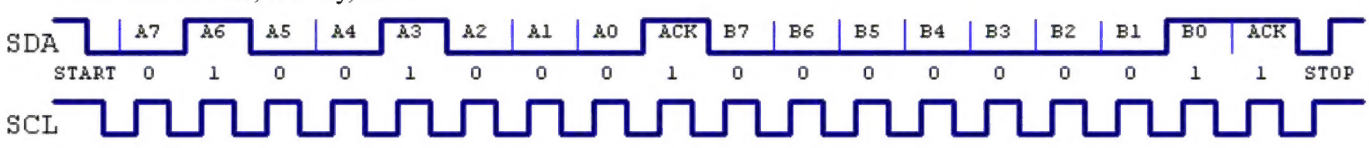
INT# is used for keyboard interrupt output and is at high level by default. INT# outputs keyboard interrupt active at low level when CH456 detects a valid key. After the MCU is interrupted, it performs a read operation to CH456, and CH456 recovers the INT# to high level and outputs the key code from SDA. The MCU gets a byte of data from SDA, among which the lower 7 bits are the key code.

The communication process between the MCU and CH456 is always divided into 6 steps. According to the operation direction of MCU, it is divided into two types: write operation for output data and read operation for input data. For the specific process, please refer to Example Program.

Write operation consists of six steps: output start signal, output byte 1, response 1, output byte 2, response 2 and output stop signal. Among them, the start signal and the stop signal are as mentioned above, response 1 and response 2 are always fixed to 1, output byte 1 and output byte 2 respectively contain 8 data bits, namely, one byte of data.

Read operation consists of six steps: output start signal, output byte 1, response 1, input byte 2, response 2 and output stop signal. Among them, the start signal and the stop signal are as mentioned above, response 1 and response 2 are always fixed to 1, output byte 1 and input byte 2 respectively contain 8 data bits, namely, one byte of data.

The following figure shows an example of write operation. The byte 1 is 01001000B, namely, 48H. The byte 2 is 00000001B, namely, 01H.



6. Operation Commands

The operation commands of CH456 are divided into three groups. Start signal, stop signal, response 1 and response 2 are the same for each command, except that the data of output bytes 1 and byte 2 are different and that byte 2 is transmitted in different direction. Bit 6 of byte 1 is the address identification bit of 2-line serial interface, which defaults to 1. The manufacturer can also provide the customized CH456 chip with default address identification bit of 0 to facilitate the parallel operation of two CH456.

6.1. Setting of System Parameter Commands

The byte 1 of this command is 01001000B, namely 48H. The byte 2 is [SLEEP][INTENS][X_INT]0[KEYB][DISP]B.

This command is used to set system-level parameters of CH456: display driver enable DISP, keyboard scanning enable KEYB, X15 interrupt output enable X_INT, display driver brightness control INTENS, low-power sleep control SLEEP.

The output is allowed to be displayed when DISP bit is 1, and the display driver is closed when DISP bit is 0.

The keyboard scan is enabled when KEYB bit is 1, and the keyboard scan is closed when KEYB bit is 0.

When the X_INT bit is 1, up to 15 LED Nixie tubes are supported. X15 or X11 pins are used for keyboard interrupt output as INT# pins. When X_INT bit is 0, it supports up to 16 LED Nixie tubes. X15 and X11 are similar to X0 ~ X10 as display drivers.

INTENS is used to control the brightness of the display driver, which contains 3 bits of data with 8 combinations: data 001B ~ 111B sets the duty ratio of the display driver as 1/8 ~ 7/8 respectively, and data 000B sets the duty ratio of the display driver as 8/8, corresponding to the highest brightness.

SLEEP is used to put CH456 into a low-power sleep state, so as to save power. CH456 in low-power sleep state can be waked up by any of the following two events. The first event is the detection of the keys scan output by KO3~KO0, and the valid key code is 40H~43H, 48H~4BH, 50H~53H, 58H~5BH, 60H~63H, 68H~6BH, 70H~73H, 78H~7BH. The second event is the reception of next operation command sent by the MCU. When CH456 is waken up, SLEEP bit is automatically reset to 0. Sleep and Wake Up operations do not affect other working states of CH456. If KEYB bit is 1, key interrupt will occur after waking up. If KEYB bit is 0, the first event waking up will not be supported, so the keyboard interrupt will not occur after waking up.

This command does not affect the data in the internal data buffer.

If X_INT=0 (default), then there is no keyboard interrupt output pin INT#, and it will disable GPO general-purpose output pin. X12 ~ X15 are used as display driver and keyboard scan output pins. CH456 supports up to 16 LED Nixie tubes.

If X_INT=1, CH456 will provide keyboard interrupt output pin INT#. Refer to the table below for the specific configurations.

Parameter	State	Additional condition parameters	Configuration function
X15_bit[0]	=0		X15 used as keyboard interrupt output pin INT# (applicable to 20-pin package)
X15_bit[0]	=1		X11 used as keyboard interrupt output pin INT# (applicable to 16-pin package) (It will affect the display of the LED Nixie tube on X0 ~ X7

			pins, only 7 segments are supported)
X15_bit[1]	=0		Disable GPO pins, X12 ~ X14 have similar functions to X10
X15_bit[1]	=1	X15_bit[0]=0	X12~X14 used as GPO general-purpose output pin, corresponding to X15_bit[4~6]
X15_bit[1]	=1	X15_bit[0]=1	X12~X15 used as GPO general-purpose output pin, corresponding to X15_bit[4~7]
X15_bit[2]	=0		All display drivers, support up to 15 LED Nixie tubes (X0 ~ X14 pins)
X15_bit[2]	=1		Halved display drivers, support up to 8 LED Nixie tubes (X0~X7 pins)

In the above table, X15_bit refers to the 8-bit data in the data register corresponding to X15 pin, which is written into the CH456 chip by loading the word data command 7EH. The default value is 00H, and X15_bit[0] refers to the value of its bit 0, and so on.

When X12 ~ X15 is used as the GPO general-purpose output pin, the output level of each GPO pin can be set by modifying the value of X15_bit[4] ~ X15_bit[7]. For example, when X15_bit[5]=0, X13 outputs low level. When X15_bit[5]=1, X13 outputs high level.

The halved display driver will increase the scan duty ratio of a single LED Nixie tube from 1/16 to 1/8, thus increasing the display brightness.

6.2. Word-data loading command

The byte 1 of the command is 011[DIG_ADDR]0B, i.e. 60H, 62H, 64H, 66H, 68H, 6AH, 6CH, 6EH, 70H, 72H, 74H, 76H, 78H, 7AH, 7CH and 7EH. Byte 2 is [DIG_DATA]B, i.e. the value between 00H and 0FFH.

"Word-data loading command" is used to write the word data DIG_DATA to the data register at the specified address DIG_ADDR. DIG_ADDR specifies the address of the data register through 4-bit data. Data 0000B-1111B specify the addresses 0-15 respectively, corresponding to 16 LED Nixie tubes driven by the pins X0~X15. DIG_DATA is 8-bit word data. For example, command data 01100000B and 01111001B means that word data 79H is written into the first data register so that the LED Nixie tube driven by the pin X0 will display E.

6.3. Read Key Code Command

The output byte 1 of this command is 01001101B, namely, 4DH (or 01001111B, i.e. 4FH). The lower 7 bits of the input byte 2 are the key code.

"Read Key Code Command" is used to get the code for the valid key that CH456 recently detects. The command is read operation, a command with data return. The MCU must first release SDA pin (three-state output is disabled or pulled up to the high level), and then CH456 outputs the key code from SDA pin, the valid data of the key code is bit 6-0 data, the bit 6 is a status code, the bits 5-0 are scan codes and key addresses.

7. Parameters

7.1. Absolute Maximum Value

Critical value or exceeding the absolute maximum value may cause the chip to work abnormally or even be damaged.

Name	Parameter description	Min.	Max.	Unit
TA	Ambient temperature during operation	-40	85	℃
TS	Ambient temperature during storage	-55	125	℃

VCC	Supply voltage (VCC is connected to the power supply, GND is grounded)	-0.5	6.0	V
VIO	Voltage on the input or output pins	-0.5	VCC+0.5	V
IMdrv	Continuous drive current of single display driver pin	0	100	mA
IMall	Total continuous drive current of all display driver pins	0	150	mA

7.2. Electrical Parameters

Test Conditions: TA=25℃, VCC=5V

Name	Parameter description	Min.	Typ.	Max.	Unit
VCC	Power supply voltage	3.0	5	5.3	V
ICC	Current of power supply		80	150	mA
ICCs	Static current (SDA is high level, KEYB=0)		0.05	0.5	mA
ICCslp	Low-power sleep current (SCL and SDA are high level by default)		0.01	0.03	mA
VIL	Low level input voltage of SCL and SDA pins	-0.5		0.8	V
VIH	High level input voltage of SCL and SDA pins	VCC/2		VCC+0.5	V
VOLx	Low level output voltage of display driver pins (-100mA)			0.7	V
VOHx	High level output voltage of display driver pins (20mA)	4.5			V
IUP	Input pull-up current of SDA pin	200	400	800	uA
VR	Default voltage threshold of power on reset	2.0	2.2	2.6	V

7.3. Internal Timing Parameters

Test Conditions: TA=25℃, VCC=5V

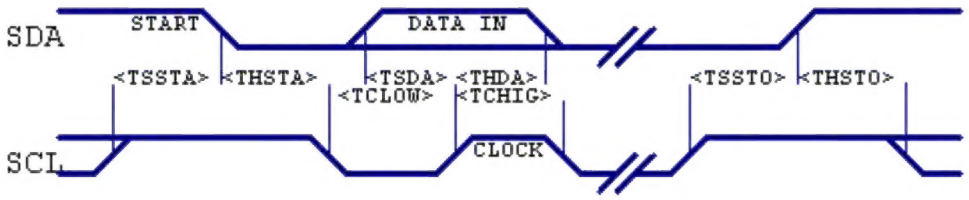
(Note: The timing parameters in this table are multiples of the built-in clock periods, and the frequency of the built-in clock decreases with the decrease of the supply voltage)

Name	Parameter description	Min.	Typ.	Max.	Unit
TPR	Reset time generated during power on detection	8	15	30	mS
TDP	Display scan period	4	8	14	mS
TKS	Key response time (two keyboard scans)	20	50		mS

7.4. Interface Timing Parameters

Test Conditions: TA=25℃, VCC=5V, refer to the attached figure

(Note: The unit of measurement in this table is nanosecond, namely, 10^{-9} seconds. If the maximum value is not indicated, the theoretical value can be infinite.)



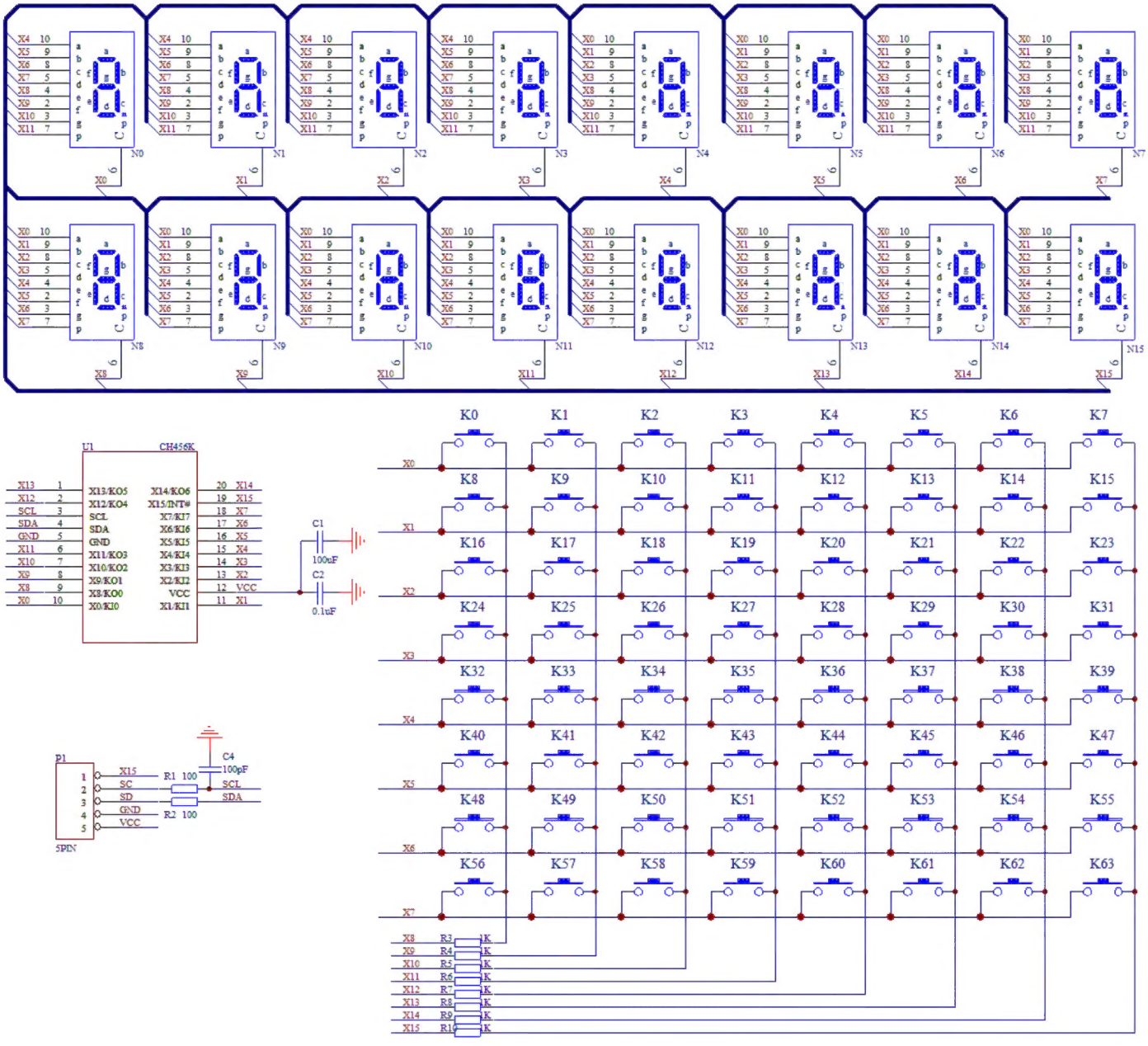
Name	Parameter description	Min.	Typ.	Max.	Unit
TSSTA	Setup time of SDA falling edge start signal	100			nS

THSTA	Hold time of SDA falling edge start signal	100			nS
TSSTO	Setup time of SDA rising edge stop signal	100			nS
THSTO	Hold time of SDA rising edge stop signal	100			nS
TCLOW	Low level width of SCL clock signal	100			nS
TCHIG	High level width of SCL clock signal	100			nS
TSDA	Setup time of SDA input data to SCL rising edge	30			nS
THDA	Hold time of SDA input data to SCL rising edge	10			nS
Rate	Average data transmission rate	0		2M	bps

8. Application

8.1. Application Circuit

CH456 can dynamically drive 16 common cathode LED Nixie tubes, and is connected to the external MCU through 2-wire serial interfaces SCL and SDA. Capacitors C2 and C1 are arranged near the power pins of CH456 to decouple the power supply and reduce the interference caused by high drive current.



8.2. Anti-interference

As CH456 drives LED Nixie tube or LED has high current, high glitch voltage will be generated on the power supply. Therefore, if the PCB wiring of the power line or ground wire is not reasonable, it may affect the stability of the MCU or CH456. It is recommended to use a thicker power line and ground wire, and connect the power supply decoupling capacitor in parallel between the positive and negative power supplies close to CH456.

For the application environment with strong interference, the MCU can refresh CH456 every a few seconds, including reloading the data register of each digital tube and restarting the display.

In addition, if CH456 is driven remotely by the I/O pin of the standard MCS-51 MCU, the pull-up capacity of the I/O pin for MCS-51 MCU should be strengthened, so as to maintain a good digital signal waveform during remote transmission. The resistance of the pull-up resistor can be 1KΩ to 10KΩ, and no pull-up resistor is required at short range.

8.3. MCU Interface Program

The CH456 chip interface program is basically compatible with that of the CH453 and CH423 chip, the subprograms and example programs of CH453 or CH423 chip can be directly used. The C program language and ASM assembly interface programs of some MCUs are provided on the website.